

Towards ontology patterns for ocean science repository integration



Pascal Hitzler

DaSe Lab for Data Semantics
Wright State University
<http://www.pascal-hitzler.de>

Robert Arko, Columbia University

Suzanne Carbotte, Columbia University

Cynthia Chandler, Woods Hole Oceanographic Institution

Michelle Cheatham, Wright State University

Timothy Finin, University of Maryland, Baltimore County

Pascal Hitzler, Wright State University

Krzysztof Janowicz, University of California, Santa Barbara

Adila Krisnadhi, Wright State University

Thomas Narock, Marymount University

Lisa Raymond, Woods Hole Oceanographic Institution

Adam Shepherd, Woods Hole Oceanographic Institution

Peter Wiebe, Woods Hole Oceanographic Institution

**The presented work is part of the NSF *OceanLink* project:
EarthCube Building Blocks, Leveraging Semantics and Linked Data
for Geoscience Data Sharing and Discovery**

EarthCube:

Developing a Community-Driven Data and Knowledge Environment for the Geosciences

“concepts and approaches to create integrated data management infrastructures across the Geosciences.”

“EarthCube aims to create a well-connected and facile environment to share data and knowledge in an open, transparent, and inclusive manner, thus accelerating our ability to understand and predict the Earth system.”

Bottom-up constructed project.

Currently first phase:

- **Integrating ocean science repositories BCO-DMO and R2R, as well as datasets from the WHOI Library, AGU abstracts, NSF projects.**
- **Demonstrable added value (faceted integrated search).**
- **Key: extensible architecture that has the potential to grow to EarthCube size**

Many axioms / strong theory

**Few models
Many inferences**



Few axioms / weak theory

**Many models
Few inferences**

Strong / many ontological commitments

**Few models
Many inferences
Not very reusable**



Weak / few ontological commitments

**Many models
Few inferences
More easily reusable**

Strong / many ontological commitments

**Few models
Many inferences
Not very reusable**

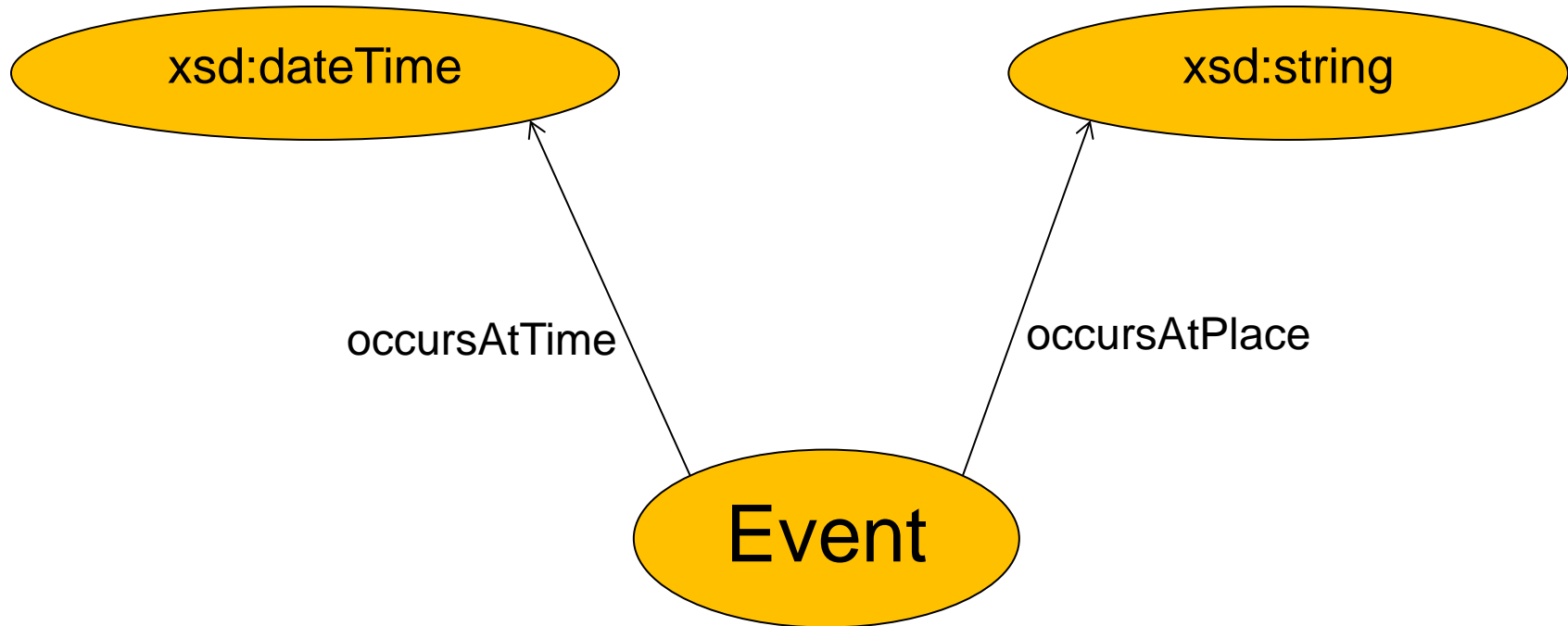
Weak / few ontological commitments

**Many models
Few inferences
More easily reusable**



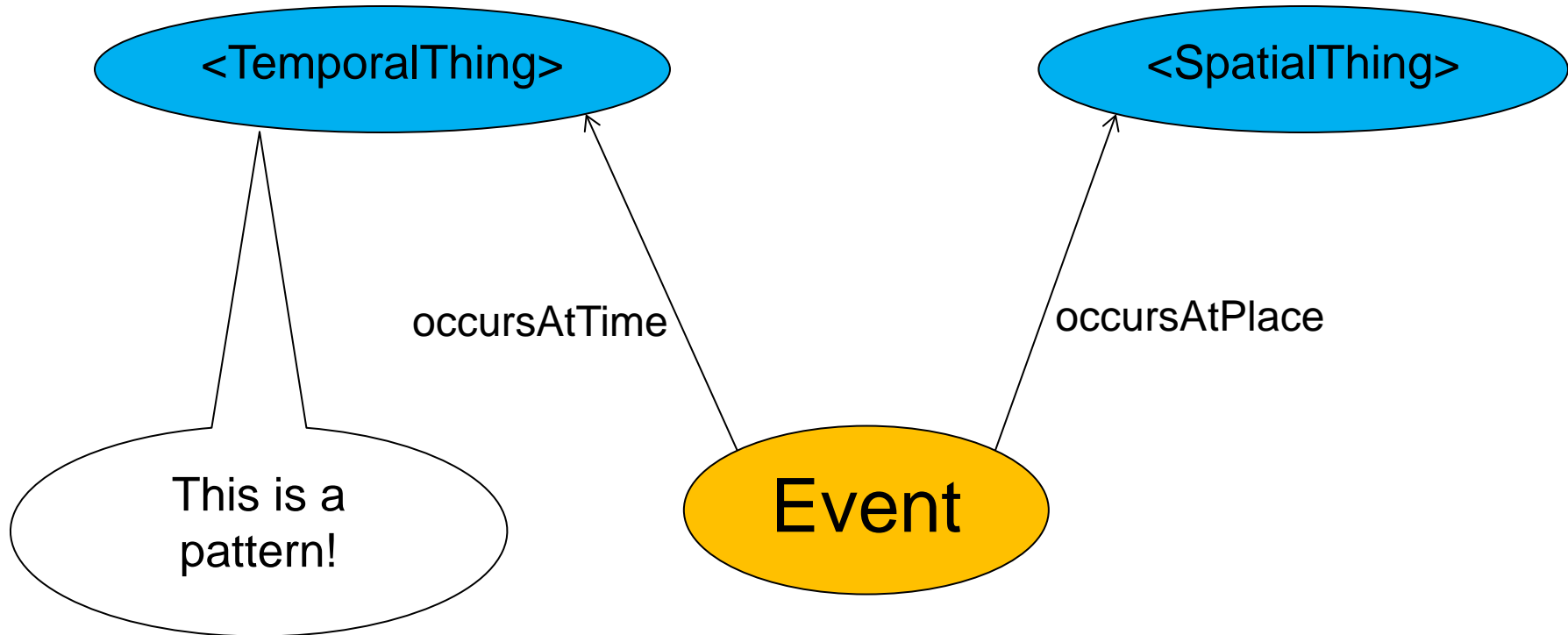
“An ontology design pattern is a reusable successful solution to a recurrent modeling problem.”

So-called *content patterns* usually encode specific abstract notions, such as process, event, agent, etc.

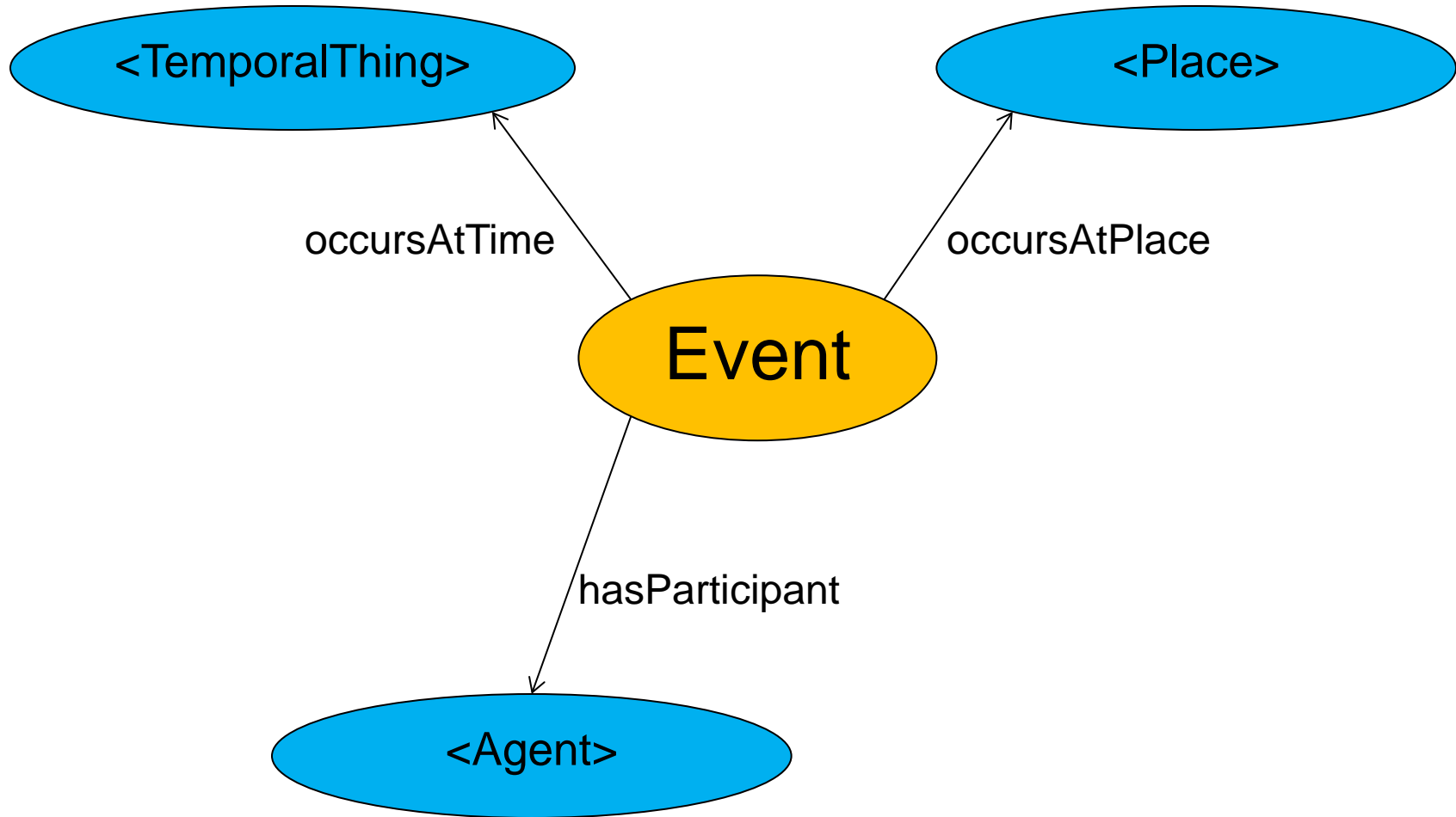


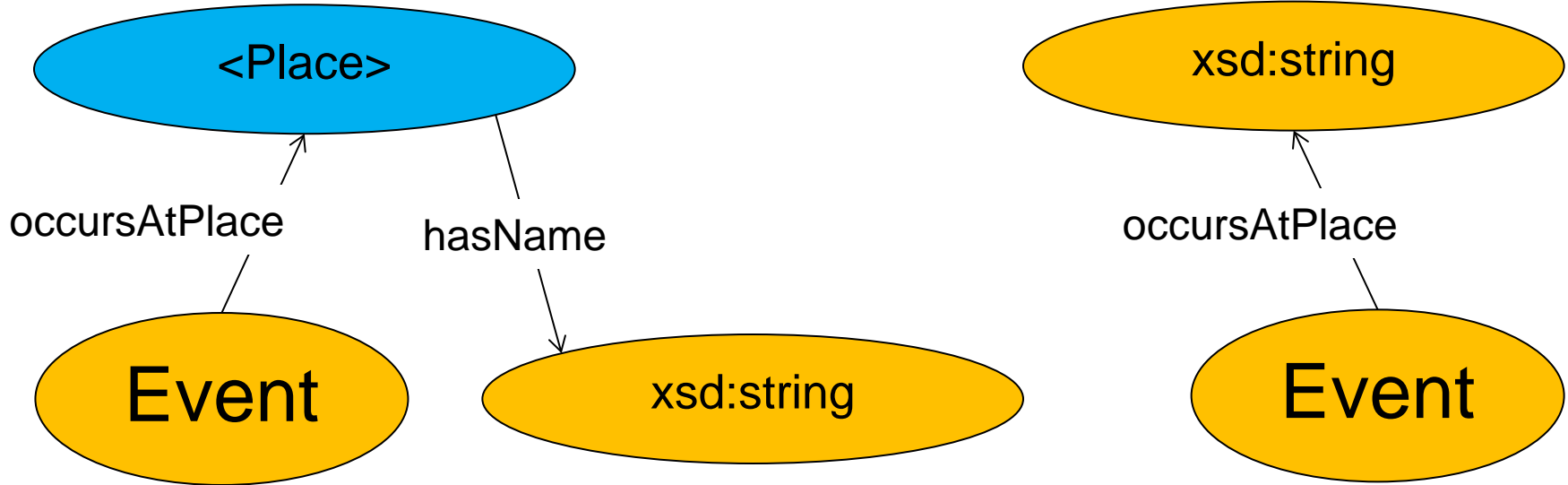
Event \sqsubseteq occursAtTime.xsd:dateTime

Event \sqsubseteq occursAtPlace.xsd:string



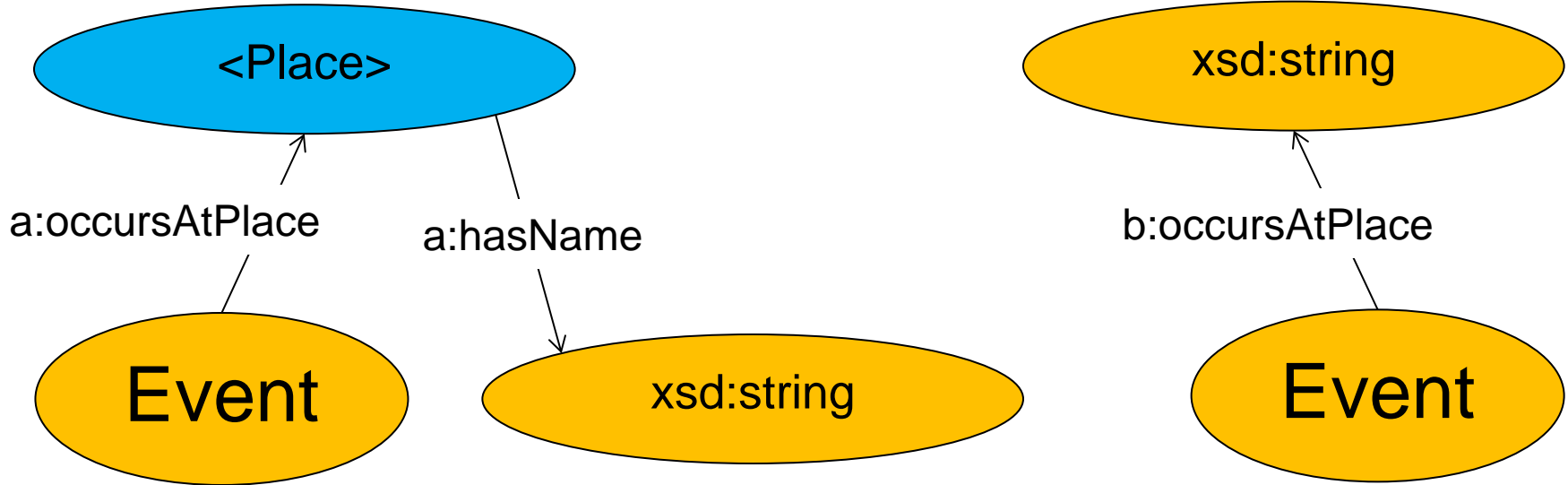
But what about events taking place in Second Life?





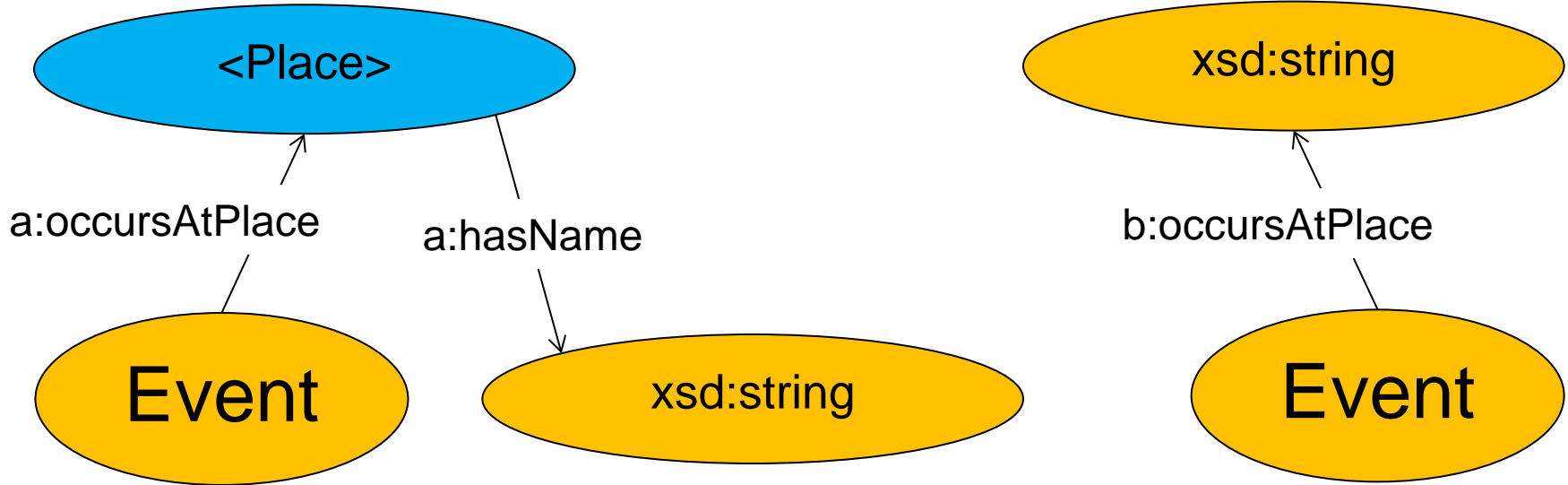
$\text{occursAtPlace} \circ \text{hasName} \equiv \text{occursAtPlace}$

There are several things wrong here!



$a:\text{occursAtPlace} \circ a:\text{hasName} \equiv b:\text{occursAtPlace}$

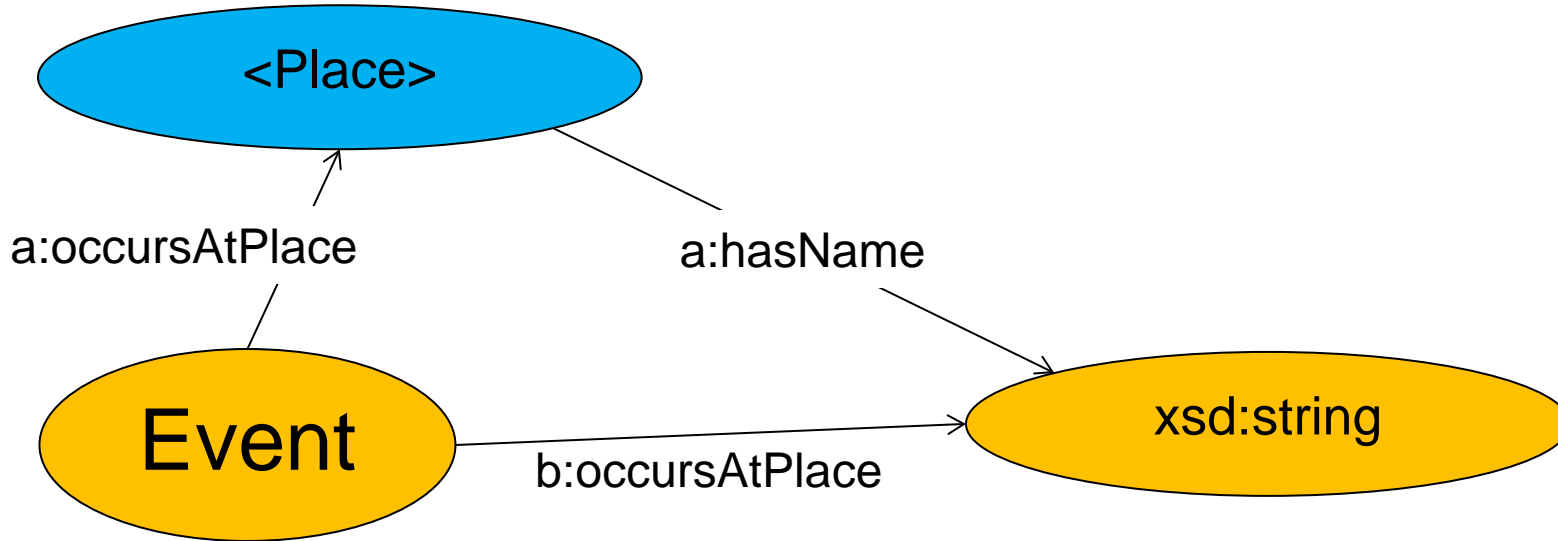
Better, but ...



$a:\text{occursAtPlace} \circ a:\text{hasName} \sqsubseteq b:\text{occursAtPlace}$

$a:\text{occursAtPlace} \circ a:\text{hasName} \sqsupseteq b:\text{occursAtPlace}$

The latter is not in OWL!

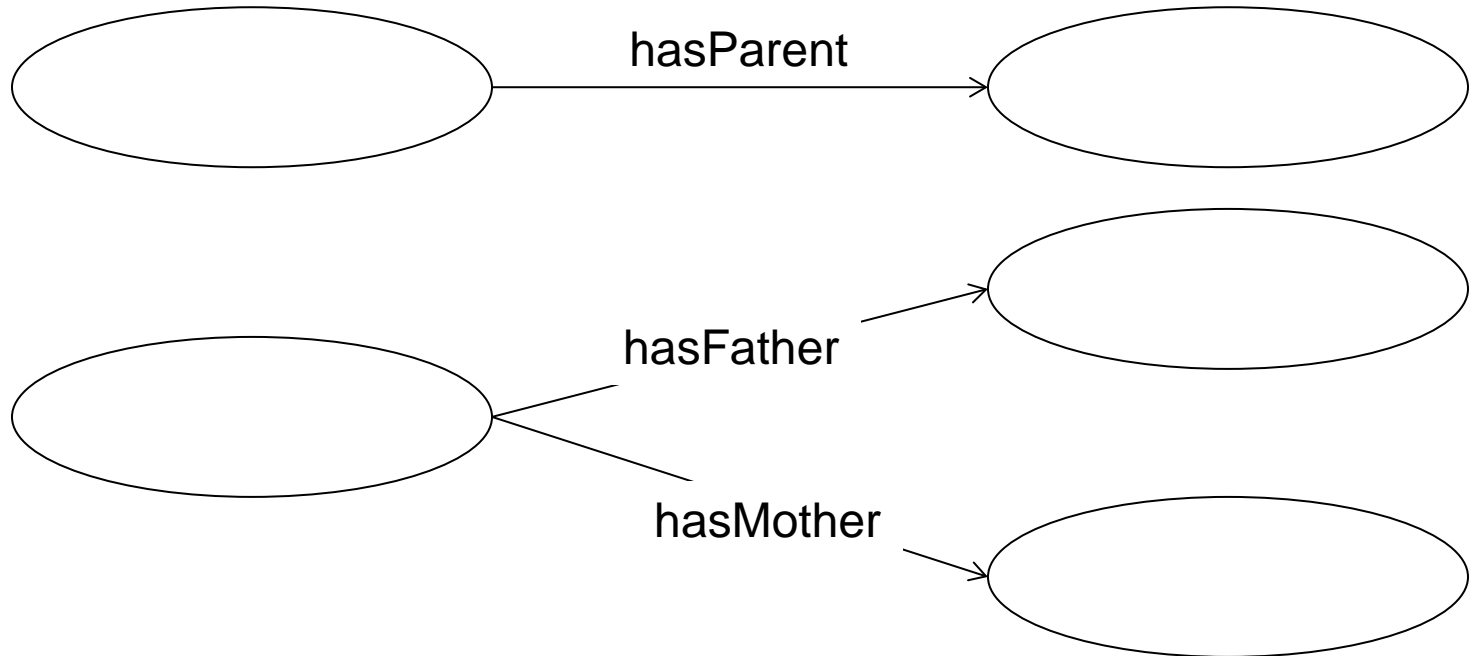


$a:\text{occursAtPlace} \circ a:\text{hasName} \sqsubseteq b:\text{occursAtPlace}$

$a:\text{occursAtPlace} \circ a:\text{hasName} \sqsupseteq b:\text{occursAtPlace}$

The latter is not in OWL!

Splitting a role:



$\text{hasFather} \sqsubseteq \text{hasParent}$

$\text{hasMother} \sqsubseteq \text{hasParent}$

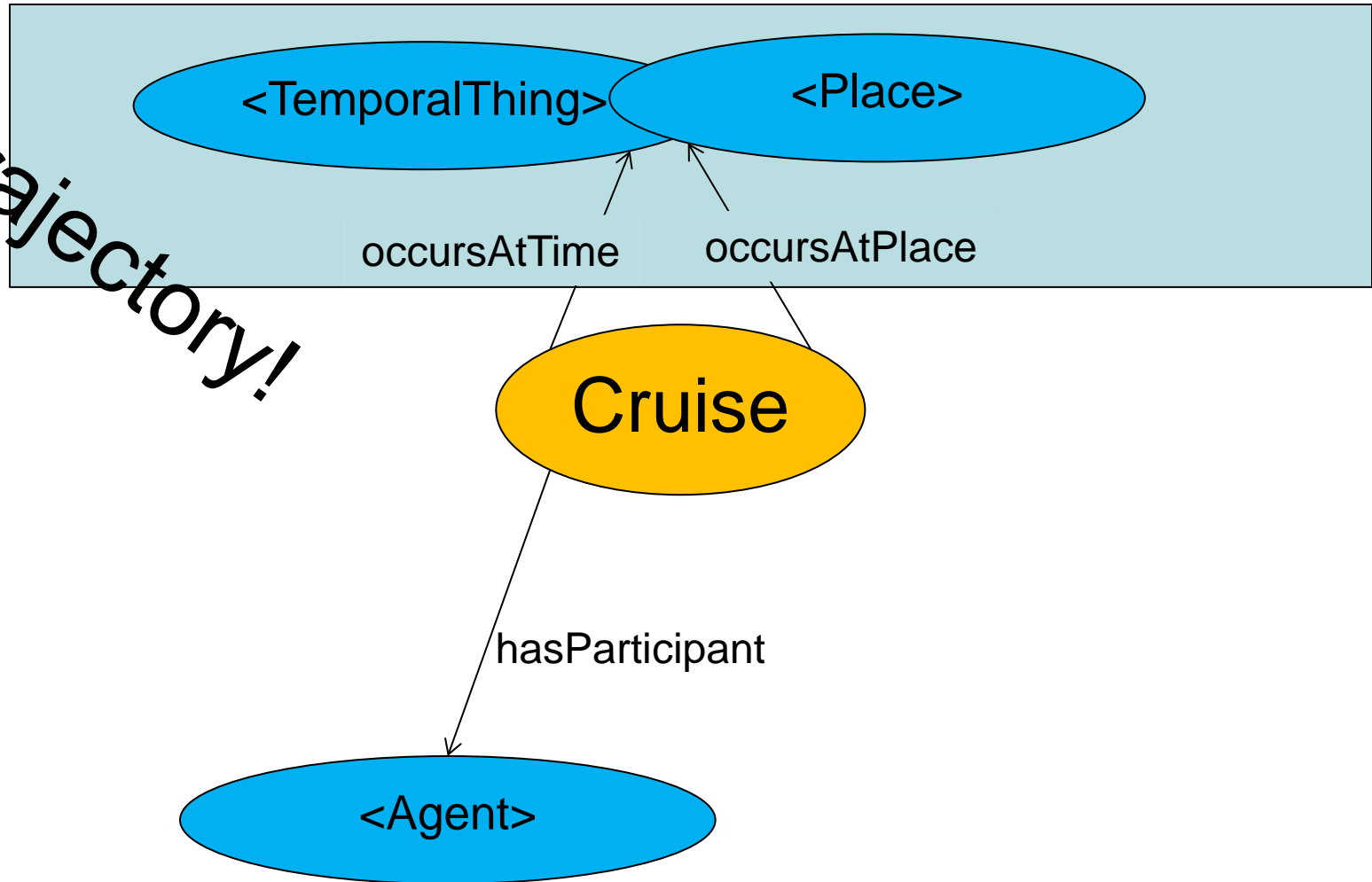
$\text{hasParent} \sqsubseteq \text{hasFather} \sqcup \text{hasMother}$

For us: *ocean science cruise*.

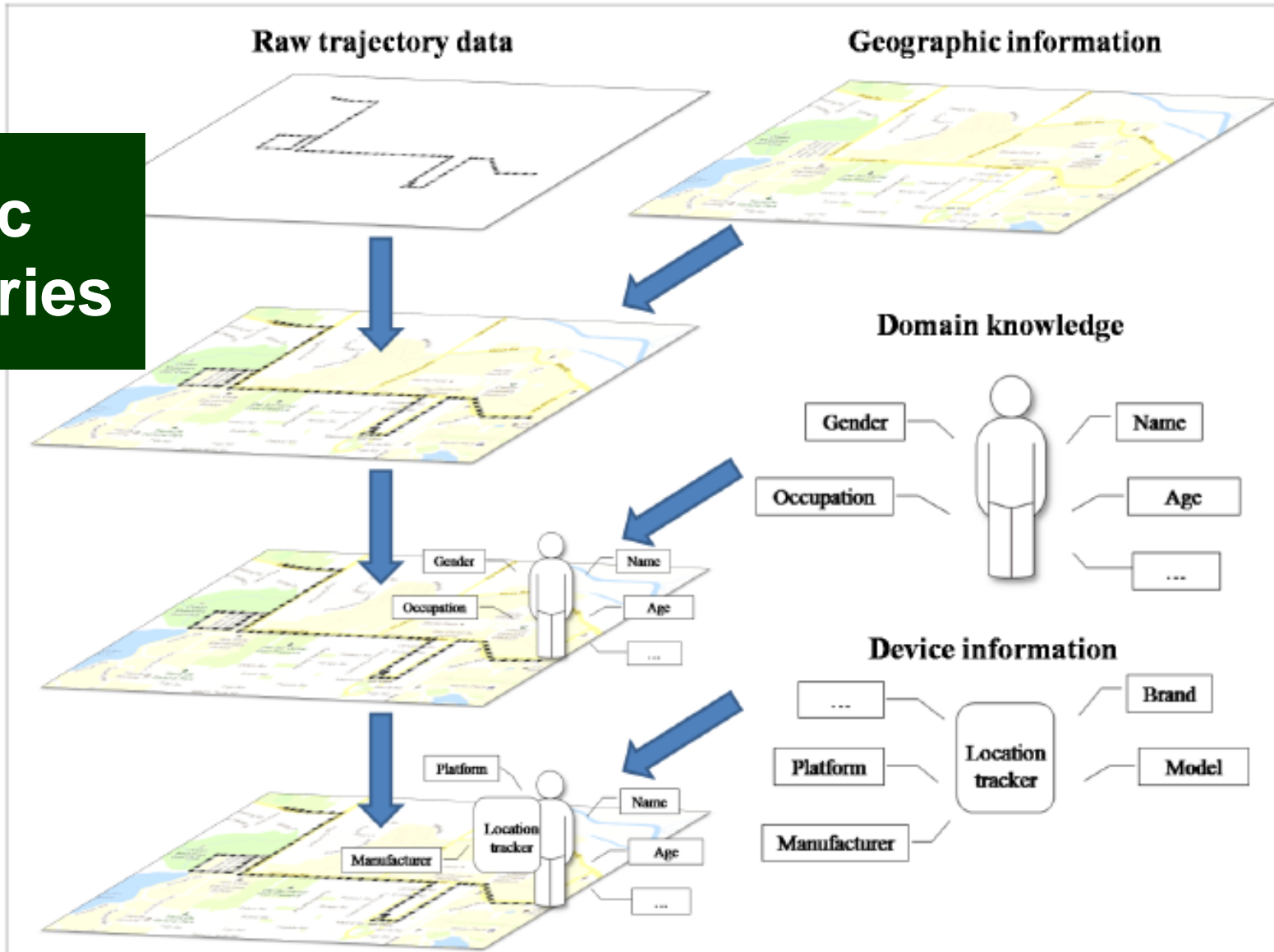
A cruise is a type of event.

But what kind of place does it occur at?

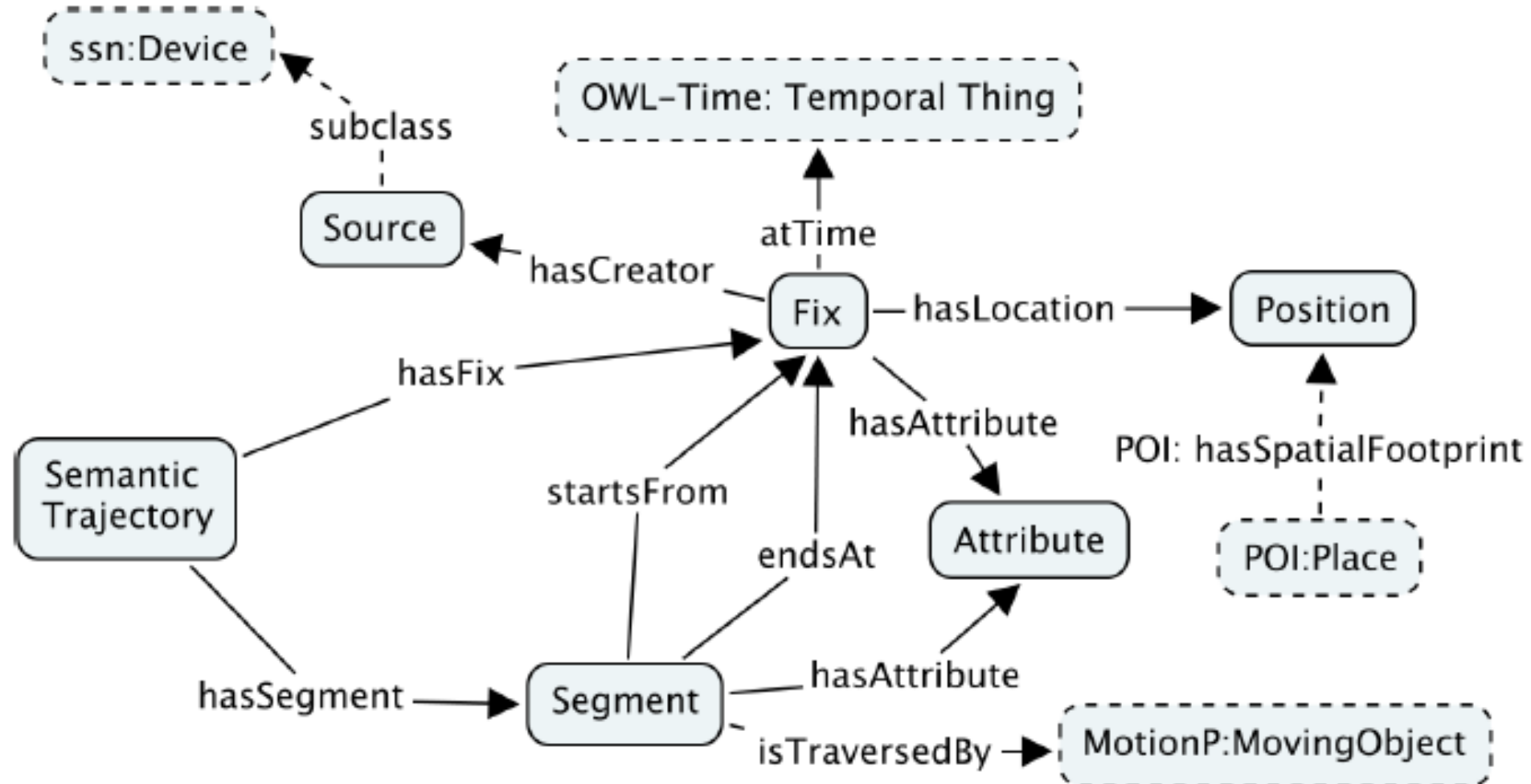
A trajectory!



Semantic Trajectories



[Hu, Janowicz, Carral, Scheider, Kuhn, Berg-Cross, Hitzler, Dean, COSIT2013]



$$\begin{aligned} \text{Fix} \sqsubseteq & \exists \text{atTime.OWL-Time:Temporal Thing} \sqcap \exists \text{hasLocation.Position} \\ & \sqcap \exists \text{hasFix}^- .\text{SemanticTrajectory} \end{aligned} \quad (1)$$

$$\text{Segment} \sqsubseteq \exists \text{startsFrom.Fix} \sqcap \exists \text{endsAt.Fix} \quad (2)$$

$$\top \sqsubseteq \leq 1 \text{startsFrom.}\top \quad (3)$$

$$\top \sqsubseteq \leq 1 \text{endsAt.}\top \quad (4)$$

$$\text{Segment} \sqsubseteq \exists \text{hasSegment}^- .\text{SemanticTrajectory} \quad (5)$$

$$\text{startsFrom}^- \circ \text{endsAt} \sqsubseteq \text{hasNext} \quad (6)$$

$$\text{hasNext} \sqsubseteq \text{hasSuccessor} \quad (7)$$

$$\text{hasSuccessor} \circ \text{hasSuccessor} \sqsubseteq \text{hasSuccessor} \quad (8)$$

$$\text{hasNext}^- \sqsubseteq \text{hasPrevious} \quad (9)$$

$$\text{hasSuccessor}^- \sqsubseteq \text{hasPredecessor} \quad (10)$$

$$Fix \sqcap \neg \exists endsAt.Segment \sqsubseteq StartingFix \quad (11)$$

$$Fix \sqcap \neg \exists startsFrom.Segment \sqsubseteq EndingFix \quad (12)$$

$$Segment \sqcap \exists startsFrom.StartingFix \sqsubseteq StartingSegment \quad (13)$$

$$Segment \sqcap \exists endsAt.EndingFix \sqsubseteq EndingSegment \quad (14)$$

$$SemanticTrajectory \sqsubseteq \exists hasSegment.Segment \quad (15)$$

$$hasSegment \circ startsFrom \sqsubseteq hasFix \quad (16)$$

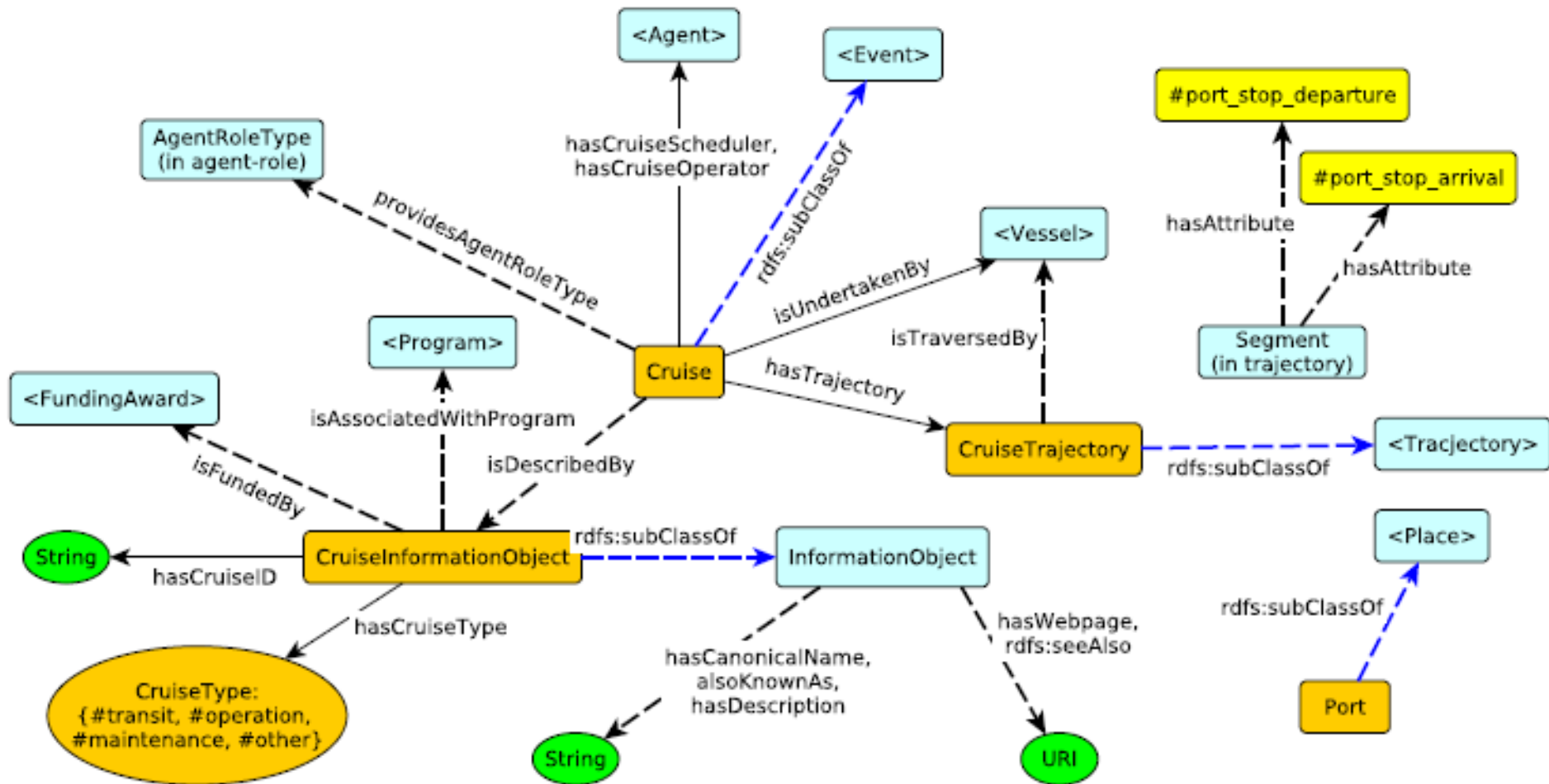
$$hasSegment \circ endsAt \sqsubseteq hasFix \quad (17)$$

$$\exists hasSegment.Segment \sqsubseteq SemanticTrajectory \quad (18)$$

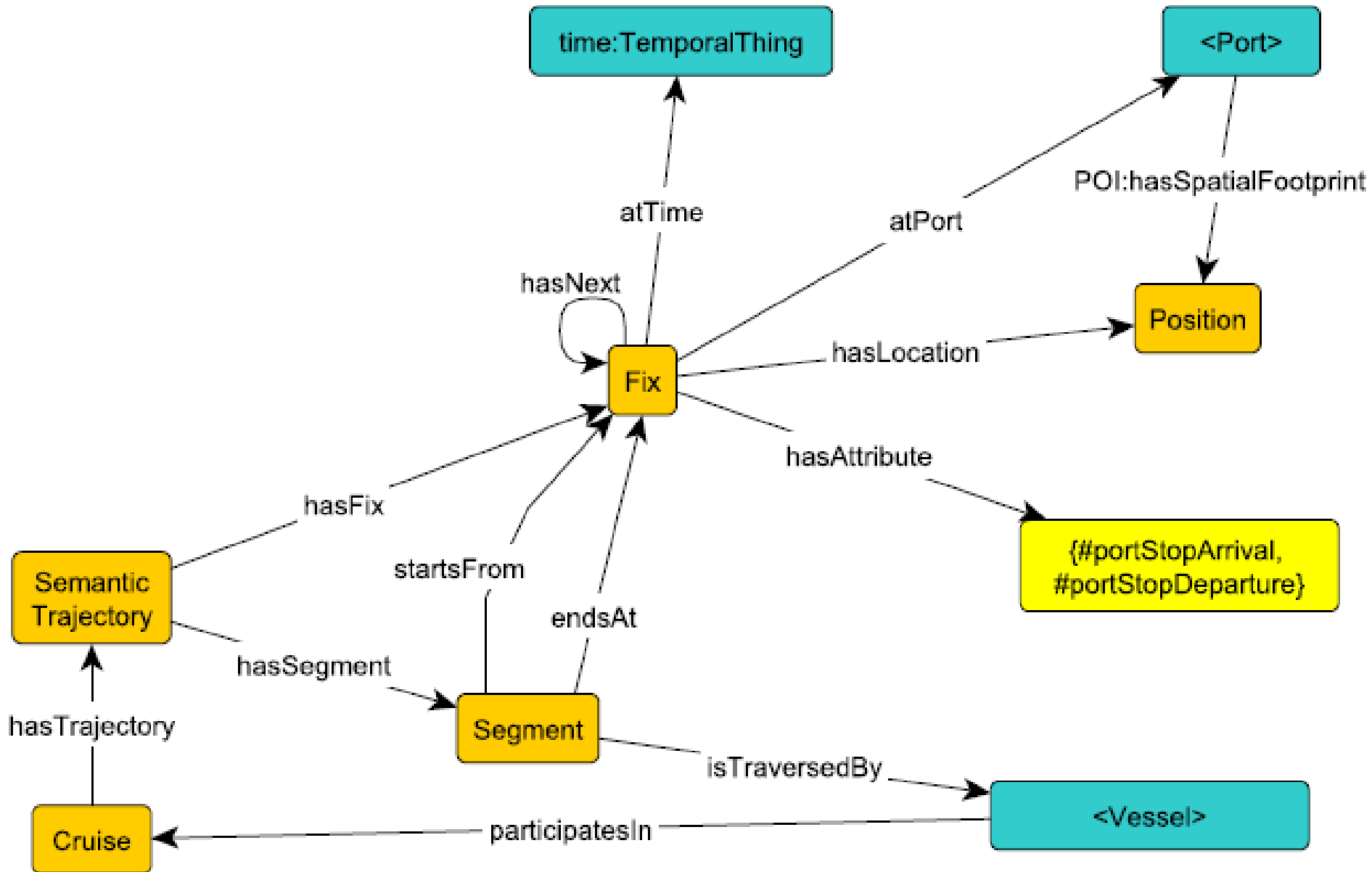
$$\exists hasSegment^- .SemanticTrajectory \sqsubseteq Segment \quad (19)$$

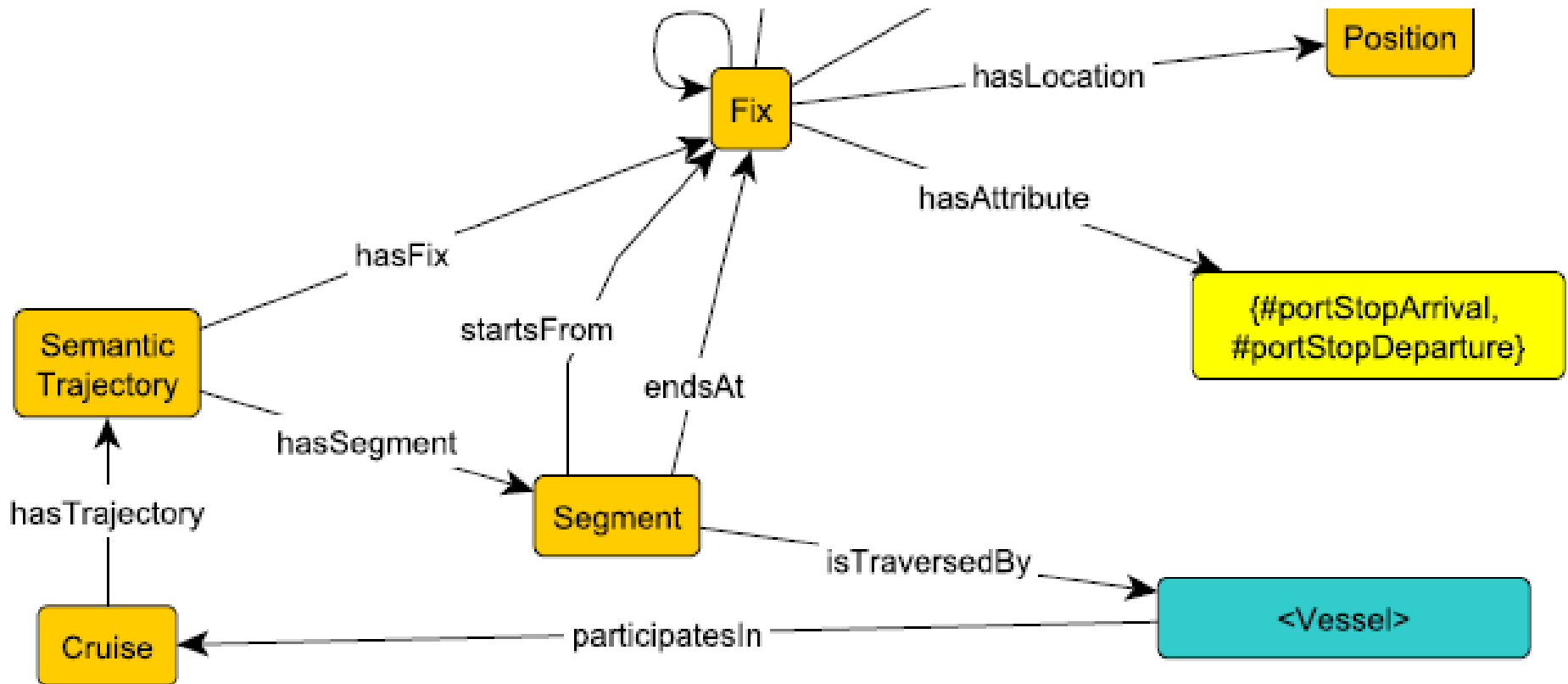
$$\exists hasFix.Segment \sqsubseteq SemanticTrajectory \quad (20)$$

$$\exists hasFix^- .SemanticTrajectory \sqsubseteq Fix \quad (21)$$

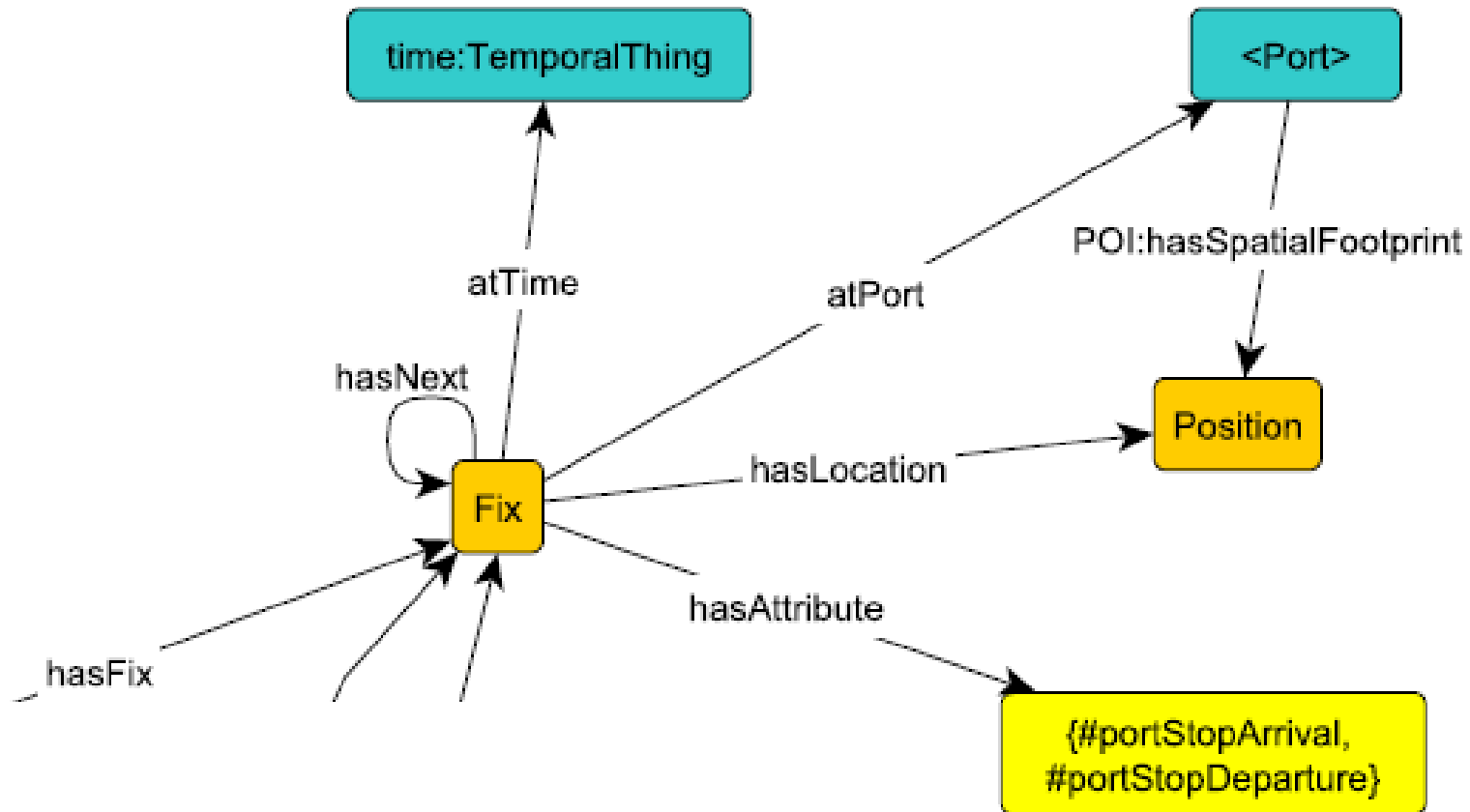


Cruise trajectory (draft)

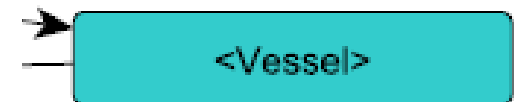


$$\begin{aligned} & \text{Cruise}(x) \wedge \text{hasTrajectory}(x, y) \\ & \quad \wedge \text{hasSegment}(y, z) \wedge \text{isTraversedBy}(z, v) \\ & \quad \rightarrow \text{participatesIn}(v, z) \end{aligned}$$


$$\begin{aligned} & \text{Cruise}(x) \wedge \text{hasTrajectory}(x, y) \\ & \quad \wedge \text{hasSegment}(y, z) \wedge \text{isTraversedBy}(z, v) \\ & \quad \rightarrow \text{participatesIn}(v, z) \end{aligned}$$
$$\text{Cruise} \equiv \exists \text{cruise.Self}$$
$$\begin{aligned} & \text{cruise} \circ \text{hasTrajectory} \circ \text{hasSegment} \circ \text{isTraversedBy} \\ & \quad \sqsubseteq \text{hasParticipant} \\ & \text{hasParticipant} \equiv \text{participatesIn}^- \end{aligned}$$



$\text{Fix}(x) \wedge \text{hasAttribute}(x, \#portStopArrival)$
 $\wedge \text{atPort}(x, y) \wedge \text{hasSpatialFootprint}(y, z)$
 $\wedge \text{hasLocation}(x, w) \rightarrow \text{locatedIn}(w, z)$



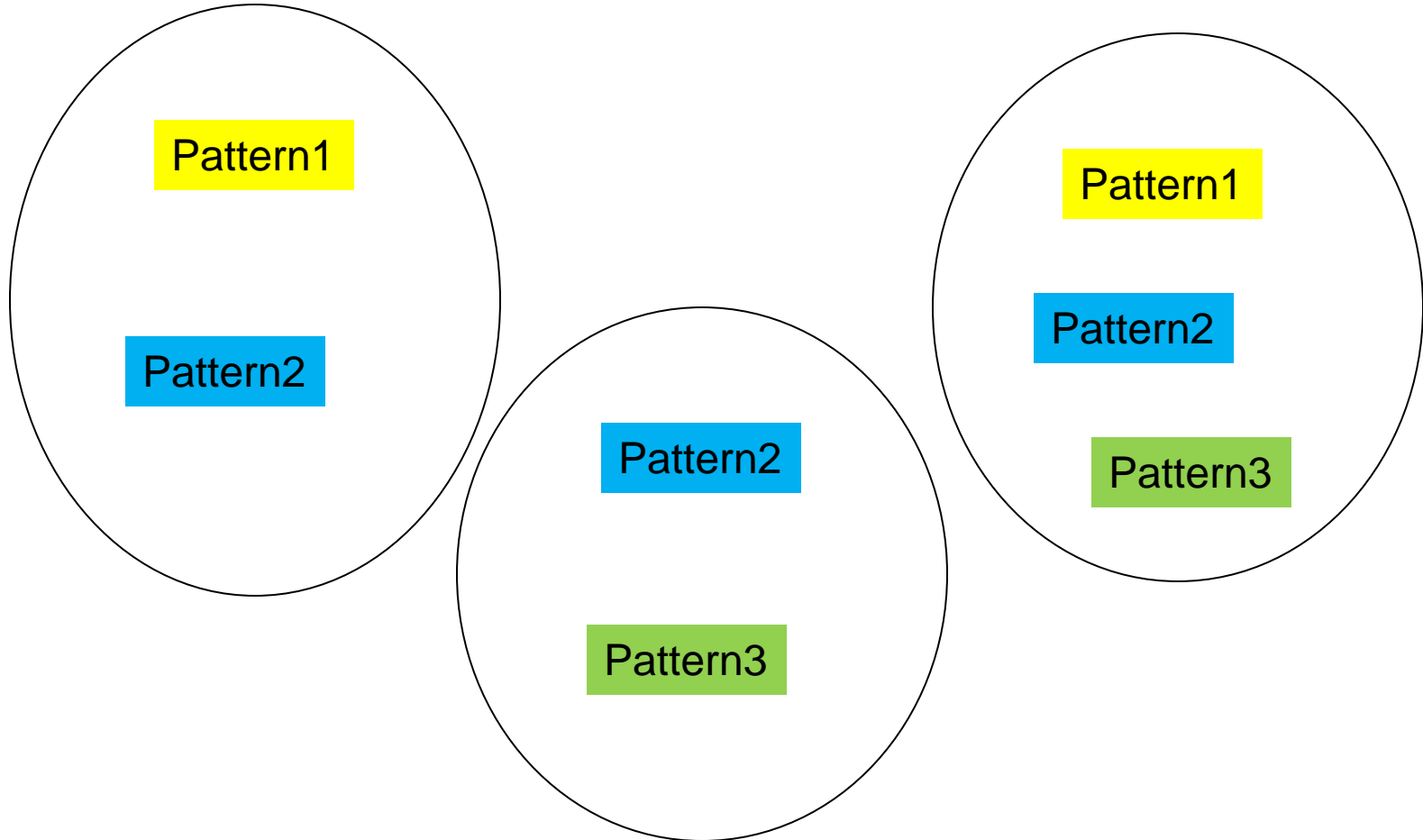
$$\begin{aligned} & \text{Fix}(x) \wedge \text{hasAttribute}(x, \#\text{portStopArrival}) \\ & \wedge \text{atPort}(x, y) \wedge \text{hasSpatialFootprint}(y, z) \\ & \wedge \text{hasLocation}(x, w) \rightarrow \text{locatedIn}(w, z) \end{aligned}$$
$$\begin{aligned} \text{Fix} \wedge \exists \text{hasTrajectory}.\{\#\text{portStopArrival}\} & \equiv \exists \text{fixps}.\text{Self} \\ & \text{hasLocation}^- \circ \text{fixps} \circ \text{atPort} \circ \text{hasSpatialFootprint} \\ & \sqsubseteq \text{locatedIn} \end{aligned}$$

Why ODPs?

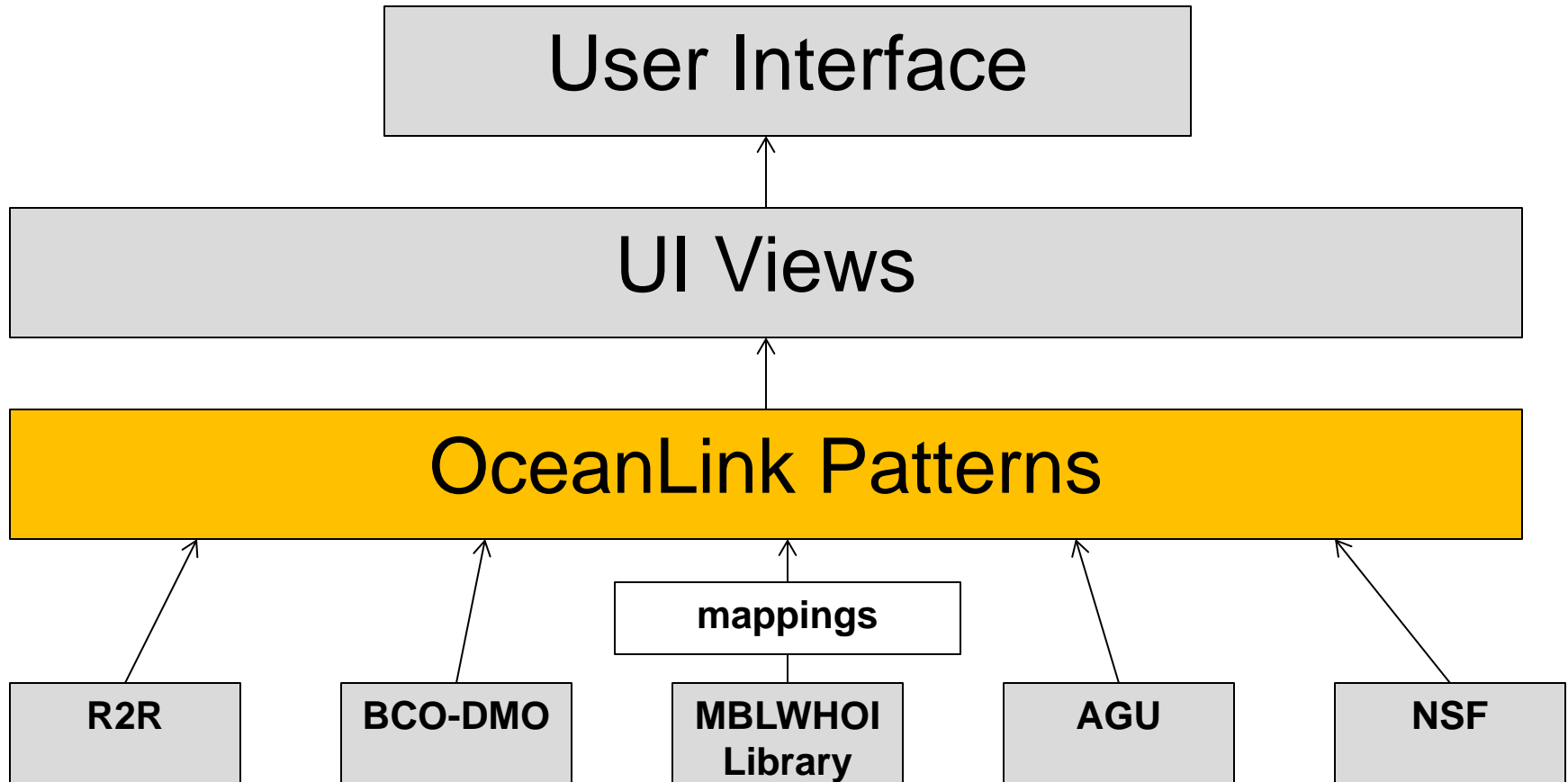
Traditionally, ODPs are thought of as building blocks for ontology modeling.

This idea is certainly valid in the context of special purpose ontology-based systems.

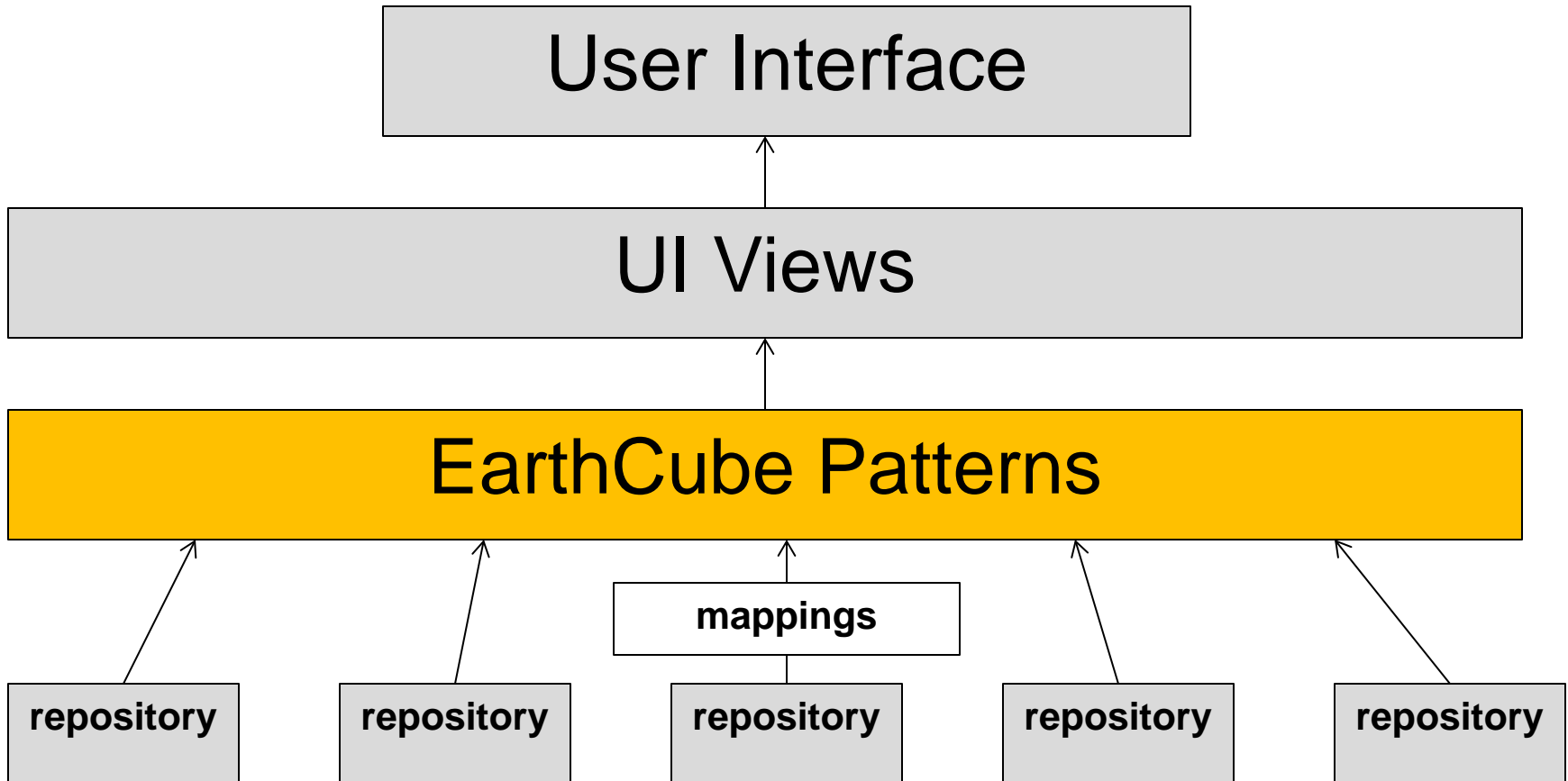
However, it can be argued that ODPs can be much more than mere building blocks.



“Horizontal” alignment via patterns



- **Pattern-driven GUIs**
- **Pattern-driven mapping tools**
- **Pattern-driven query rewriting**
- **Pattern-driven reasoning modularization**
- ...



Thanks!

- BCO-DMO: Biological & Chemical Oceanography Data Management Office, <http://www.bco-dmo.org/>
- R2R: Rolling Deck to Repository, <http://www.rvdata.us>
- OceanLink website and publications are forthcoming
- Yingjie Hu, Krzysztof Janowicz, David Carral, Simon Scheider, Werner Kuhn, Gary Berg-Cross, Pascal Hitzler, Mike Dean, Dave Kolas, A Geo-Ontology Design Pattern for Semantic Trajectories. In: Thora Tenbrink, John G. Stell, Antony Galton, Zena Wood (Eds.): Spatial Information Theory - 11th International Conference, COSIT 2013, Scarborough, UK, September 2-6, 2013. Proceedings. Lecture Notes in Computer Science Vol. 8116, Springer, 2013, pp. 438-456.
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